MINISTRY OF THE ENVIRONMENT

MATHEMATICS

FOR

WATER AND WASTEWATER OPERATIONS

1976

Training and Certification Section
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OBJECTIVE OF THIS MANUAL

An operator of a water or wastewater treatment plant should routinely evaluate the efficiency of the plant and of the individual units. To do so, with any degree of accuracy, requires that the operator be familiar with basic mathematical concepts.

The objective of this manual is to help the operator to determine process efficiency through the use of mathematical calculations rather than "trial and error" methods. This manual will not dwell on mathematics in general but rather is intended to act as a guide to the operator in the sense of providing examples of typical "in-plant" calculations.

Water Treatment Plant Operators are required to perform the following in application of their knowledge to "in-plant" processes:

- manipulation of equations and the utilization of formulae
- area, volume and ratio calculations
- dosage calculations for chlorine and other chemicals used in water treatment
- rate of flow calculations.

Wastewater Treatment Plant Operators are required to perform the following in the application of their knowledge to "in-plant" processes:

- manipulation of equations and utilization of formulae
- area, volume and ratio calculations
- dosage calculations for chemicals used in wastewater treatment
- rate of flow calculations
- detention times
- Activated Sludge Calculations including:
    - -mixed liquor suspended solids determination (MLSS)
    - -volatile suspended solids determination (MLVSS)

- food/microorganism ratio (F/M Ratio)
- sludge wasting
- specific up-take rate (SUR)
- bio-chemical oxygen demand (BOD) load calculations.

INSTRUCTIONS FOR USE OF MANUAL

This manual is specially designed to be used in conjunction with the manuals for Basic Sewage Treatment Operation Course, the Basic Water Treatment Operation, the Surface Water Treatment Workshop and the Activated Sludge Workshop. This manual will accompany the training materials sent out to trainees prior to courses.

Prior to attending a course or workshop, the contents of this and the course manual must be reviewed by the trainee. The appropriate section(s) detailed below, is (are) to be completed prior to coming on the course and submitted at the time of course registration. The manual will then be graded and problem areas noted. A review will be conducted during the course/workshop to clarify problem areas. The manual will be returned to the trainees for their own future use.

a. Section C - To be completed by those attending the BASIC WATER TREATMENT OPERATION COURSE.

b. Section H - To be completed by those attending the SURFACE WATER TREATMENT WORKSHOP.

c. Section D - To be completed by those attending the BASIC SEWAGE TREATMENT OPERATION COURSE.

d. Section F and H - To be completed by those attending the ACTIVATED SLUDGE WORKSHOP.

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SECTION A

PRACTICAL MATH FOR WATER & WASTEWATER TREATMENT PLANT OPERATORS

In most plants routine laboratory tests are performed daily to ensure that the plant is effectively tuned.to operate under optimum conditions. The analyses of samples, as determined in the laboratory, will assist the operator in deciding whether any adjustments are necessary to the treatment units to achieve a desirable degree of efficiency of operation. This necessitates that the operator be able to apply the laboratory data made available to him. It is therefore essential that he has a good sound knowledge of basic mathematics to help him more fully understand the significance of test results.

This manual will deal specifically with "in-plant" situations, in an effort to help the operator cope with the necessary calculations, as opposed to attempting to provide a complete understanding of mathematics in general. As a result, the following material contains sample problems indicative of "in-plant" situations as well as a "play-by-play" description of what an operator might consider when solving these. It is intended that the operator will take it upon himself to become familiar with the more fundamental concepts of mathematics if necessary by reviewing high school mathematics books. Reference can also be made to the publication available from AWWA, WPCF and commercial companies.

THE APPROACH

When one sits down to solve a mathematical problem, how should he approach it? Firstly, don't write anything until you have read the question and determined what is asked. Quite often the questions are "word problems", so rather than focus attention on the numbers given or the equations included in a problem, we should first ask ourselves some very basic questions about the mathematics problem itself;

(1) What are you asked to find?
(2) What concept is involved (e.g. volume, area)?
(3) Can you draw a diagram or get a picture in your mind of what is going on?
(4) What are you told about the situation you are asked to solve?
(5) Are there any formulae you have come across that are applicable to the problem?
(6) Is there any information not given to you or is it hidden somewhere in the question, perhaps in another form or with different units that need conversion?

Up to this point, you have not used any mathematics. All you have done is examine the situation depicted in the problem. This is why you must understand the "in-plant" processes involved; if you don't, you will find it difficult to do the calculations. Remember that mathematics is a two-way street. With mathematics you can verify that your observations are in line or once given the answer (e.g. from test results), you can decipher what is going on in the plant. There are some basic math concepts that once mastered will make your calculations seem simple. It has already been stressed that mathematics problems are word problems. Once you understand what the situation is, you convert the words into math symbols and eventually equations. The equations quite often look very complex but once you realize that all they do is represent words and ideas concerning plant processes, you will find they aren't difficult at all. As a

result, you should make yourself familiar with the operations and processes involved when dealing with equations. You must be aware of "units"; they tell you in what terms you are talking (e.g. inches, cubic feet per second, etc.) and also you will have to learn how to convert from one unit to another, (inches to feet, cubic feet to gallons,) or from the Imperial system (lbs., gals.) to the Metric system (grams, litres).

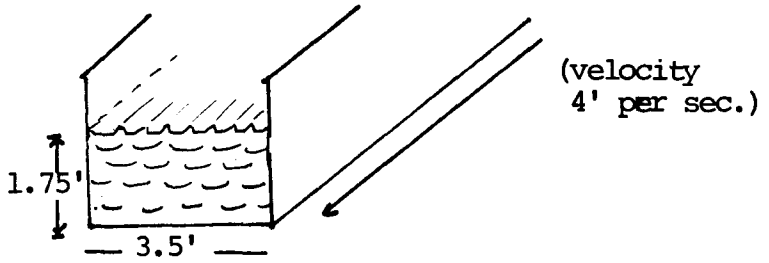
In summary, if you understand completely the processes taking place in your plant and if you make an effort to learn the relatively few basic mathematics concepts involved, math for your in-plant calculations will present no problem at all.

RATE OF FLOW CALCULATIONS

These calculations are important as they provide data that is necessary in determining the cost of treatment and the efficiency of the process control equipment. The accuracy of the flow meters and pumping capacities can be checked and the measurement of flows, contributed by various sources, such as ground water run-off or industrial wastes, can be estimated with some degree of accuracy. Rates of flow must be determined for proper sizing of clarifiers, aeration tanks, grit chambers, etc.

EXAMPLE 1:

A channel 3.5 ft. wide has water flowing to a depth of 1.75 ft. What is the GPM (gallons per minute) FLOW in the channel if the velocity of the water is 4 ft. per second.



RATE OF FLOW = WIDTH x DEPTH x VELOCITY

= 3.5ft x 1.75ft x 4ft/sec

= 24.5ft^3/sec. or 24.5 cubic feet per second

CHECK UNITS -

$$ft. \times ft. \times \frac{ft.}{sec.} = \frac{ft.^3}{sec.}$$

However, we are asked to find the flow in GPM

Given that 1 ft^3 contains 6.24 gals

$24.5ft^3/sec = 24.5ft^3/sec \times 6.24\ gals/ft^3$

$= 152.88\ gals/sec.$

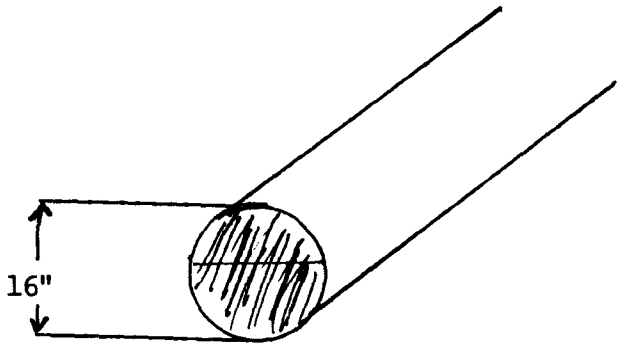
Therefore if the flow is 152.88 gals/sec

Then the flow per minute or 60 secs. = 152.88 gals x 60

= 9172.8 gals/min.

EXAMPLE 2:

What is the GPD (gallons per day) FLOW in a 16 inch diameter pipe that is flowing 3/4 full if the velocity is 125 ft/min?



VOLUME OF FLOW = CROSS SECTIONAL AREA x VELOCITY

$= .75\ \pi r^2$ x Velocity

$= (.75)(3.14) \times (.67)' \times (.67)' \times 125$ ft/min

$= 132.14\ ft^3/min$

Above we have figured out the CROSS SECTIONAL AREA (using THE AREA OF A CIRCLE FORMULA) of the pipe and multiplied it by .75, since the flow only uses 3/4 of the area. Then we simply multiply and arrive with an answer in terms of ft^3/min.

We are asked to put the answer in terms of GPD

$$\text{In GPD, } 132.14\ ft^3/min = 132.14 ft^3/min \times 6.24 \frac{gals}{ft^3} \times 1440\ min/day$$

$$= 1{,}187{,}357\ gals/day$$

Check Units -

$$\frac{ft^3}{min} \times \frac{gals}{ft^3} \times \frac{min}{day} = \frac{gals}{day}$$

DOSAGE CALCULATIONS

It is very necessary for a plant operator to know how to calculate the dosages of the various chemicals used in water and wastewater treatment. It is important to be accurate when figuring the dosage as too little chemical may be ineffective and too great a dosage a waste of money. As a result, for process control the exact dose of chemical to be added must be determined for the purposes of efficient operation of equipment and economy.

EXAMPLE 1:

The chlorine demand of an effluent is 15 mg/l. How many pounds of chlorine will be required to satisfy the demand by a flow of 4.5 MGD (million gallons per day)?

In this question it will be necessary to utilize our knowledge of mg/l to pounds conversions (see Appendix 1).

$$15 \text{ mg/l} = 15 \text{ ppm} = \frac{15 \text{ lbs } Cl_2}{1{,}000{,}000 \text{ lbs/day}}$$

$\therefore$ for every 1,000,000 lbs. of water of flow, we will need to use 15 lbs. chlorine.

If the flow is 4.5 MGD and we know 1 gal weighs 10 lbs. we have 45 million lbs. of water of flow per day.

$$4.5 \times 10^6 \text{ gals} \times 10 \text{ lbs/gal} = 45 \times 10^6 \text{ lbs}$$

$\therefore$ for 45 million lbs. flow we will use

$$45 \times 10^6 \text{ lbs/day} \times \frac{15 \text{ lbs } Cl_2}{10^6 \text{ lbs/day}} = 675 \text{ lbs } Cl_2$$

DOSAGE CALCULATIONS

EXAMPLE 2:

A chlorinator is set to feed 210 lbs/day of chlorine. If the average daily flow through the plant is 1.75 MGD, what is the DAILY AVERAGE CHLORINE DOSAGE IN mg/l?

We must convert lbs/day dosage to mg/l dosage.

We are told we use 210 lbs chlorine for every 1.75 million gallons water or 17.7 million lbs water (1 gal = 10 lbs).

$$\frac{\text{210 lbs/day Cl}}{\text{(1.75 MGD)(10 lbs/gal) Flow}} = \frac{\text{210 lbs/day Cl}}{\text{17.5 M lbs/day Flow}}$$

$$= \frac{\text{12 lbs Cl}}{\text{1 mil lbs/day}} = \underline{\underline{\text{12 mg/l}}}$$

Above we divided pounds of chlorine used per day by the flow (in pounds) and found we used 12 lbs chlorine for every million pounds flow or 12 mg/l.

HYPOCHLORITE CALCULATION:

Definition - A hypochlorite is a compound of chlorine and another chemical usually applied in the form of a solution for disinfection purposes.

EXAMPLE 1:

The secondary effluent at a treatment plant required a chlorine dosage of 98 lbs/day for disinfection purposes. If we are using a solution of hypochlorite containing 60% available chlorine, how many pounds/day hypochlorite will be required ?

SOLUTION:

We are told in the problem that 60% of the hypochlorite is available chlorine which is the portion of the solution capable of disinfecting

$$\therefore \quad (60\%)\ (\text{hypochlorite solution}) = \text{available chlorine}$$

$$(60\%)\ (\text{lbs/day hypochlorite}) = 98 \text{ lbs/day Cl.}$$

$$.6 \ X \text{ lbs/day} = 98$$

Solving for X we have -

$$X \text{ lbs/day hypochlorite} = \frac{98}{.6}$$

$$X = 163.3 \text{ lbs/day hypochlorite}$$

HYPOCHLORITE CALCULATIONS

EXAMPLE 2:

A hypochlorite solution contains 5% available chlorine. If 8 lbs of available chlorine are needed to disinfect a main, how much 5% solution would be required?

We are told 8lbs. of chlorine will do the job of disinfection.

By a 5% solution we mean that 5% by weight of the solution is to be made up of chlorine. So 100 lbs of 5% hypochlorite solution will contain 5 lbs chlorine.

or

100 lbs 5% solution contains 5 lbs chlorine

20 lbs. 5% solution contains 1 lb. chlorine

$\therefore$ 8 lbs chlorine diluted to 5% will cause the solution to weigh 8 x 20 lbs = 160 lbs hypochlorite solution

or, as in Example 1,

(5%)(lbs/day hypochlorite) = Available Chlorine

5% lbs/day hypochlorite = 8 lbs Cl^2

$\therefore$ lbs/day hypochlorite = $\frac{8 \text{lbs}}{0.5}$ = 160 lbs.

PERCENT

EXAMPLE 1:

A solution weighing 80 lbs contains 85% water and the remainder is lime. What is the weight of lime?

The total solution weighs 80 lbs or represents 100%;if the water represents 85% then the lime represents:

$$\underset{\text{Total Weight}}{100\%} - \underset{\text{Water}}{85\%} = 15\% \text{ lime}$$

$$\therefore \text{ Weight of lime} = 15\% \times 80 \text{ lbs}$$
$$= .15 \times 80 \text{ lbs} = 12 \text{ lbs.}$$

EXAMPLE 2:

A solution of 200 lbs in weight contains 176 lbs of water and the rest is Alum.

(a) What percentage of the mixture is water?

(b) What percentage of the mixture is Alum?

SOLUTION -

(a) In the above question we are told the total weight of the mixture is 200 lbs or 100%.

Weight of water is 176 lbs.

And to find the percentage simply multiply by 100%.

$$\therefore \frac{\text{Weight of Water}}{\text{Total Weight}} = \frac{176}{200}$$

$$\frac{176}{200} \times 100\% = 88\% \text{ water}$$

(b) Obviously if 88% of the mixture is water then -

$$\underset{\text{(total weight)}}{100\%} - \underset{\text{(water)}}{88\%} = 12\% \text{ alum}$$

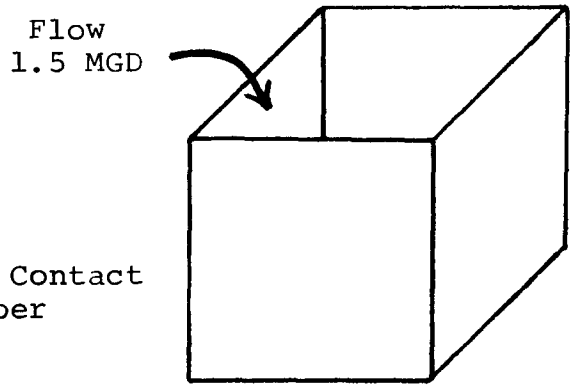
DETENTION TIME

As an operator, you are aware that during various stages in the treatment process the flow must be contained in certain tanks or sections of the plant for specified periods of time, the reason being that it takes time for the various treatment operations to occur. In the sewage treatment process there are varying detention times recommended for the treatment of certain kinds of raw sewage in the aeration section. In the water treatment process, it is necessary to retain the flow in the coagulation - flocculation section for a period long enough for the floc to form but not too long so as to begin to break up the floc. In the design phase sizing of clarifiers and aeration tanks is determined according to both the detention time required and rate of flow.

EXAMPLE:

A water treatment plant has an average daily flow of 1.5 MGD. If the average detention time in the chlorine contact chamber is 15 min., what should the volume of the chamber be, in Cubic Feet?

DIAGRAM



SOLUTION:

If 1.5 MG flows through in 1 day or 24 hrs. then in 1 hr. what is the flow?

$$\frac{1{,}500{,}000 \text{ gals}}{24 \text{ hrs.}} = 62{,}500 \text{ gals/hr.}$$

What is the flow in 15 min or ¼ hr.

$$\frac{62{,}500 \text{ gals/hr}}{.25 \text{ hr.}} = 15{,}625 \text{ gals/}\tfrac{1}{4} \text{ hr.}$$

If this is the expected flow in 15 min., then common sense tells us that the chlorine contact chamber must be big enough to contain at least this flow, 15,625 gals.

However, we are asked to give our answer in cubic feet(ft^3)

Remember in 1 cu. ft. of water there are 6.24 gals.

$\therefore$ in 15,625 gals there are $\frac{15{,}625 \text{ gals}}{6.24 \text{ gals } ft^3} = 2504 \text{ } ft^3$

or using the formula -

$$\text{Volume (V)} = \text{Rate of flow (R)} \times \text{Time (T)}$$

$$= RT$$

$$= 1{,}500{,}00 \frac{\text{gals}}{\text{day}} \times T$$

$$\text{and } T = 15 \text{ min} = \frac{15 \text{ min}}{1440 \text{ min/day}} = 0.0104166 \text{ days}$$

$$V = 1{,}500{,}000 \frac{\text{gals}}{\text{day}} \times 0.0104166 \text{ days}$$

$$= 15625 \text{ gals or as above } 2504 \text{ } ft^3$$

SECTION C

BASIC MATH - WATER TREATMENT OPERATION

1. Calculate the surface area of a rectangular settling tank 60 feet long and 20 feet wide.

2. Calculate the surface area of a circular sand filter that is 21 feet in radius.

3. What is the volume in cubic feet of a chlorine contact chamber that is 25 feet long, 8 feet wide, and 6 feet deep?

4. What is the volume in gallons of a cylindrical storage tank that is 14 feet in diameter and 15 feet high?

5. What is the volume contained by 252 feet of 4" pipe?

   a) in cubic feet?

   b) in gallons?

6. If a pump pumps 300 gallons in 20 minutes, what is the pumping rate in -

   a. GPM (gallons per minute)?

   b. GPH (gallons per hour)?

7. How much water will an 80 GPM pump pump in 5 minutes?

8. A 2,700 gallon storage tank supplies alum for water treatment at a rate of 4.5 gallons per hour. How often will the tank need refilling?

12.

9. The prechlorination chamber at a water treatment plant has a volume of 50,000 gallons. If the flow rate out of the tank is 0.2 MGD, what is the <u>average detention time</u> in hours?

10. How many <u>pounds</u> of chlorine are required each day to treat 4.0 MGD with chlorine at 5.0 ppm?

13.

11. A gas chlorinator treats 0.6 MGD with 4.5 lb. of chlorine each day. Calculate the dosage rate. The residual is measured at 0.3 ppm. What is the <u>chlorine demand</u>

    a. in mg/l ?

    b. pounds/day ?

12. In the chart below you are required to determine the pounds of chemical that will be required to dose at the rate indicated along the top of the chart in relationship to the amount of water flowing in which is indicated along the side.

dosage rate / amt. of water	1.0 ppm	2.0 ppm	4.0 ppm	10 ppm	0.5 ppm
1,000,000 lb.					
4,000,000 lb.					
20,000,000 lb.					
500,000 lb.					
200,000 gal.					

13. In the chart below you are required to determine the dosage in either ppm or mg/l that coincide with the flow indicated on the vertical scale and the pounds of alum indicated on the horizontal scale.

amt. of alum / amt. of water	1.0 lb.	2.0 lb.	5.0 lb.	20 lb.	0.4 lb.
1,000,000 lb.					
5,000,000 lb.					
10,000,000 lb.					
200,000 lb.					

14. A liquid mixture of 214 lb. weight in total contains 186 lb. of water and the rest is alum.
a) Calculate the percent that is water.
b) Calculate in percent the fraction that is alum.

15. A solution of water and powdered carbon is to be 85% water. If the total volume of solution required is 800 gallons, how much powdered carbon is needed?

16. A hypochlorite solution contains 12% available chlorine. If 8 lb. of available chlorine are needed to disinfect a main, how many lb. of 12% solution are required? How many gallons?

BASIC WATER TREATMENT MATH (EXTRA PRACTICE CALCULATIONS)

Problem Set 2

---

1. Calculate the volume contained by 100 feet of pipe that is 14" in diameter.

2. A rectangular storage tank for an alum solution that is 20 feet long, 15 feet wide, and 10 feet deep after filling takes 30 days to empty. What is the average rate at which the alum solution if being used up? (Express the answer in GPD)

3. A solution is composed of three substances - water, powdered carbon and alum and the total weight is 2,000 lbs. Calculate the weight of each substance if it is known that 70% is water and 25% is carbon.

4. A water treatment plant has a flow of 0.6 MGD. If the average detention time in the chlorine contact chamber is to be 12 minutes, what should the volume of the chamber be?

5. A 0.0005% concentration of copper sulphate is suggested for controlling algae in a certain reservoir. The volume of the reservoir is 40 million gallons. How many pounds of copper sulphate are required?

6. A well produces 0.4 MGD and is chlorinated by using 56 lb. of chlorine each week. Calculate the dosage rate.

7. An operator is attempting to chlorinate a well water supply using a hypochlorinator. The well pump rate is 100 GPM, the hypochlorite solution is 20% available chlorine and the required dose is 2.5 ppm. How many gallons of hypochlorite solution should be used each day?

SECTION D

BASIC MATH - WASTEWATER OPERATIONS

1. What is the surface area of a rectangular clarifier 20 feet wide and 60 feet long?

2. What is the surface area of a circular clarifier 21 feet in radius?

3. What is the volume in cubic feet of a chlorine contact chamber 25 feet long, 8 feet wide, and 6 feet deep ?

4. What is the volume in gallons of a cylindrical storage tank that is 14 feet in diameter and 15 feet high ?

5. If a pump pumps 300 gallons in 20 minutes, what is the pumping rate in

   a. GPM ?

   b. GPH ?

6. An 80 GPM pump operates for 5 minutes. How much water is pumped?

7. A 2,700 gallon alum storage tank supplies alum for phosphorus removal treatment at a rate of 4.5 gallons per hour. How often will the tank need refilling?

10.

8. Water flows through a rectangular channel 3 feet wide and 2 feet deep at a speed of 8 ft./sec. What is the flow rate in -

   a) $ft.^3/sec.$?

   b) gallons per minute?

11.

9. The aeration section of a 0.2 MGD plant has a volume of 50,000 gallons. What is the average detention time?

10. In the chart below you are required to determine the pounds of chemical that will be required to dose at the rate indicated along the top of the chart in relationship to the amount of water flowing in which is indicated along the side.

amt. of water \ dosage rate	1.0 ppm	2.0 ppm	4.0 ppm	10 ppm	0.5 ppm
1,000,000 lb.					
4,000,000 lb.					
20,000,000 lb.					
500,000 lb.					
200,000 gal.					

11. In the chart below you are required to determine the dosage in either ppm or mg/l that coincide with the flow indicated on the vertical scale and the pounds of alum indicated on the horizontal scale.

amt. of water \ amt. of alum	1.0 lb.	2.0 lb.	5.0 lb.	20 lb.	0.4 lb.
1,000,000 lb.					
5,000,000 lb.					
10,000,000 lb.					
200,000 lb.					

12. How many pounds of chlorine are required each day to dose the effluent of a 4.0 MGD plant at 5.0 ppm?

13. A gas chlorinator is set to dose the effluent of a 0.6 MGD with 24 lb of chlorine each day. If the chlorine demand is 3.0 ppm, calculate the chlorine residual in,

(a) mg/l

(b) pounds/day

BASIC WASTEWATER TREATMENT OPERATION
(EXTRA PRACTICE CALCULATIONS)

Problem Set 2

---

1. An aerator tank is 8 feet deep, 20 feet wide and 50 feet long. Calculate its volume in -

   a) cubic feet

   b) gallons

2. A 120,000 gallon tank has a detention time of 5 hours. Calculate the flow in -

   a) gallons per hour

   b) gallons per day

3. The venturi meter at a plant records a fairly constant flow of 400 GPM while at the same time the operator observes that the flow in the channel (2 feet wide and 1.5 feet deep) is about 1 foot per second. Is the meter recording accurately?

4. If the chlorine dosage rate at a 0.3 MGD plant is 6.0 ppm, how many pounds of chlorine are consumed each day?

5. Raw sewage entering the primary clarifier has a suspended solids content of 250 mg/l. The concentration is reduced to 150 mg/l in the primary effluent and 15 mg/l in the final effluent. Calculate the efficiency (in percent) of the -

   a) primary section

   b) the whole plant

ACTIVATED SLUDGE CALCULATIONS

EXAMPLE:

MIXED LIQUOR SUSPENDED SOLIDS DETERMINATION (MLSS)

GIVEN:

Sample volume of mixed liquor used = 50 ml
Dried disc weight (Tare Weight) = 0.2157 gm
Dried weight of disc + solids = 0.4376 gm

Determine the MLSS in mg/l

$$MLSS = \frac{(B-A) \times \overset{(1)}{1000} \times \overset{(2)}{1000}}{V} *$$

Where

B = Dried weight of disc and solids in grams
A = Dried disc weight (weight in grams)
V = Volume of sample used in ml

$$\therefore MLSS = \frac{0.4376 \text{ gm} - 0.2157 \text{ gm} \times 1000 \times 1000 \text{ mg/l}}{50 \text{ ml}}$$

$$= \frac{(.2219 \text{ gm}) \times 1000 \times 1000 \text{ mg/l}}{50}$$

$$= 4438 \text{ mg/l}$$

* MLSS is usually reported in mg/l. In the formula the
#1 - 1000 is there to convert the weight to mg's while
#2 - 1000 ensures that the figures are relative to 1000 ml or 1 litre. This is to report the MLSS in mg/l.

F/M RATIO

F/M RATIO (FOOD/MICROORGANISM RATIO) - is the relationship between the weight of food (measured by the BOD of the aerator influent) and the weight of microorganisms in the aerator (as measured by the MLVSS).

EXAMPLE 1:

A conventional activated sludge treatment plant receives a daily flow of 4.5 MGD with a primary effluent BOD of 165 mg/l. If 15,000 lbs of MLVSS are maintained in the aerator, what is the F/M ratio?

SOLUTION:

FIRST, BEFORE determining the F/M loading ratio, we must calculate the pounds of BOD entering the aerator daily. Therefore, we must convert mg/l BOD to pounds of BOD daily.

$$(165 \text{ mg/l})\ (4.5 \text{ MGD})\ \ (10 \text{ lbs/gals}) = 7425 \text{ lbs BOD/day}$$

$$\therefore \quad F/M = \frac{\text{lbs BOD daily}}{\text{lbs MLVSS in aerator}} = \frac{7425 \text{ lbs BOD}}{15{,}000 \text{ lbs MLVSS}}$$

$$= .495$$

SLUDGE AGE

Sludge Age refers to the average number of days a particle of suspended solids is maintained in the aeration section. In a conventional activated sludge system the sludge age is generally within the range of 3½ to 7 days. The calculation is therefore used to determine what should be the proper amount of activated sludge in the aeration section. Basically the calculation involves the determination of the quantity of solids entering the aerator daily in relationship to the quantity of suspended solids (MLSS) already contained in the section.

EXAMPLE

Given a suspended solids concentration of 110 mg/l in the primary effluent, an aeration tank volume of .35 million gallons, a MLSS concentration of 2850 mg/l and a daily plant flow of 2.5 MGD, calculate the Sludge Age.

SOLUTION

lbs/day Suspended Solids in Primary Effluent

$$110 \text{ mg/l} = \frac{110}{1{,}000{,}000} \times 2{,}500{,}000 \text{ gals} \times 10 \text{ lbs/gal}$$

$$= 2750 \text{ lbs SS/day}$$

lbs of MLSS contained within Aerator

$$2850 \text{ mg/l} = \frac{2850}{1{,}000{,}000} \times 350{,}000 \text{ gals} \times 10 \text{ lbs/gal}$$

$$= 9975 \text{ lbs MLSS in aerator}$$

Since pounds of incoming suspended solids per day in relationship to pounds of MLSS is expressed as days Sludge Age.

$$\therefore \frac{9975 \text{ lbs MLSS}}{2750 \text{ lbs SS/day}} = 3.63 \text{ days Sludge Age.}$$

SLUDGE WASTING:

In order to attain an equilibrium in the food to microorganisms ratio, it will be necessary to "waste" some activated sludge. Continuous wasting that is proportional to the degree of organic loading in the incoming flow or batch wasting, at times of low hydraulic loads, are two ways in which this process may be achieved. The amount of sludge to be wasted can be determined if the suspended solids in the aeration tank and sludge return are measured. The excess solids are determined by comparing the desired solids in the system with the existing solids.

EXAMPLE

Given a sludge return concentration of 9800 mg/l suspended solids, an MLSS of 5300 mg/l, and the aeration tank capacity of 275,000 gallons, calculate -

a) how many gallons of sludge must be diverted to waste in order to reduce the MLSS to 4200 mg/l?

b) What would be the pumping rate per hour

(i) if wasted continuously over a 24-hour period?

(ii) if batch wasted over a 6-hour period?

SOLUTION:

Formula -

$$X = \frac{(M_o - M_1)\ V}{R}$$

Where M_o = MLSS (mg/l)

M_1 = Required MLSS (mg/l)

V = Volume aeration tank (gal)

R = suspended solids in sludge return (mg/l)

X = gallons to waste

a) The solution of the above problem requires only substitution of given values into the formula.

$$X = \frac{(5300 \text{ mg/l} - 4200 \text{ mg/l})\ (275{,}000 \text{ gals})}{9800 \text{ mg/l}}$$

$$= \frac{1100 \text{ mg/l} \times 275{,}000 \text{ gals}}{9800 \text{ mg/l}}$$

$$= 30{,}867 \text{ gals.}$$

b) (i) Amount of sludge to be wasted = 30,867 gals

Time period of wasting = 24 hrs

$\therefore$ Pumping Rate = $\frac{30,867 \text{ gals}}{24 \text{ hrs}}$ = 1286.13 gals/hr.

(ii) Amount of sludge to be wasted = 30,867 gals

Time period of wasting = 6 hrs

$\therefore$ Pumping Rate = $\frac{30,867 \text{ gals}}{6 \text{ hrs}}$ = 5144.5 gals/hr.

CLARIFIER UPFLOW RATE

The amount of wastewater flowing into a clarifier relative to the surface area of the clarifier is known to affect the settleable solids and BOD removal efficiency during sedimentation.

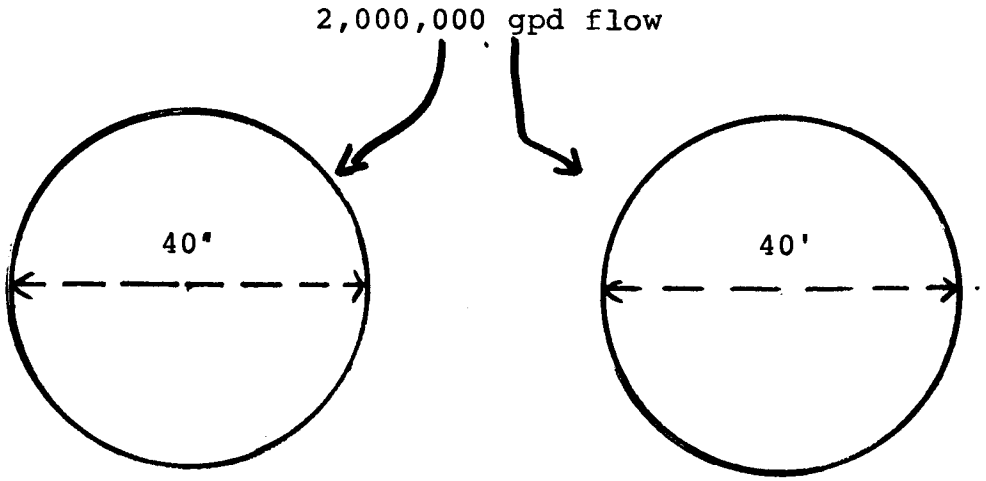
A means of determining this "surface loading rate" is to compare the number of gallons of wastewater entering the clarifier to the surface area of the clarifier. The units of measurement are therefore gallons of wastewater daily per square foot of clarifier surface area or -

$$\frac{\text{average daily flow (gals)}}{\text{surface area of final clarifier (sq.ft.)}}$$

EXAMPLE:

The flow to a treatment plant is 2 MGD. If there are two final clarifiers, each with a diameter of 40 feet, calculate the clarifier upflow rate.

SOLUTION:



Final Clarifiers

Referring to the above formula, note the information required. Given the daily flow as 2 MGD, it is necessary to calculate the surface area of the final clarifiers.

$\therefore$ using area of a circle formula

$$A = r^2 \text{ or } \frac{\pi d^2}{4}$$

given a diameter of 40', the surface area of one final clarifier is

$$\frac{3.14\ (40)^2}{4} = 1256 \text{ sq.ft.}$$

However, there are two final clarifiers; therefore total clarifier surface area is

$$2 \times 1256 \text{ sq.ft.} = 2512 \text{ sq.ft.}$$

$\therefore$ Upflow Rate $= \frac{2{,}000{,}000 \text{ gals daily}}{2512 \text{ sq.ft.}}$

$= 796.18$ gals/sq.ft./day.

SLUDGE VOLUME INDEX (SVI)

The Sludge Volume Index (S.V.I.) is defined as the volume, in millilitres, that is occupied by 1 gram of activated sludge after a 30 minute settling test. Normal activated sludge generally has an SVI value in the range of 70-125.

EXAMPLE:

If the mixed liquor settled to 285 ml or 28.5% after the 30 minute settling test and the concentration of the mixed liquor suspended solids (MLSS) is 3250 mg/l, what is the SVI.

SOLUTION:

$$SVI^* = \frac{\text{30 min. settling test result (ml)} \times 1000}{\text{MLSS (mg/l)}}$$

$$= \frac{285 \text{ ml} \times 1000}{3250 \text{ mg/l}}$$

$$= \underline{\underline{87.7}}$$

*Alternate formula for SVI = $\frac{\text{30 minute settling test result}}{\text{MLSS in grams}}$

RESPIRATION RATES

The respiration rate, in the context of an activated sludge plant, is the rate at which the micro-organisms within the aeration tanks use up oxygen. Another phrase for this process is Oxygen Uptake Rate. Respiration rates or uptake rates vary according to the solids concentration in the aeration tank. As a result, the uptake rate is frequently expressed as the "Specific Uptake Rate" (SUR) and this means the amount of oxygen utilized in one hour by one gram of mixed liquor volatile suspended solids.

EXAMPLE

Oxygen consumption of a mixed liquor was measured and recorded over a period of time. From the information provided below, prepare a graph and -

a. calculate the oxygen uptake rate
b. given a volatile suspended solids value of 2400 mg/l calculate the specific uptake rate.

TIME (min)	DO (mg/l)
0	7.8
1	7.7
2	7.3
3	6.8
4	6.4
5	6.0
6	5.4
7	4.8
8	4.3
9	3.7
10	3.0

a) It can be seen from the record that the DO value at time zero is 7.8 mg/l and the value at time 10 minutes is 3.0 mg/l. By subtracting the lower DO value from the higher and dividing by the time interval, the uptake rate can be determined as follows:

$$\frac{7.8 \text{ mg/l} - 3.0 \text{ mg/l}}{10 \text{ min.}} = .48 \text{ mg } O_2\text{/l/min.}$$

But the oxygen uptake rate is expressed in the units mg O_2/l/hr.

$$\therefore \text{uptake rate} = .48 \text{ mg } O_2\text{/l/min. x 60 min/hr.}$$

$$= 28.8 \text{ mg } O_2\text{/l/hr.}$$

b) Specific Uptake Rate (SUR) mg O_2/hr/gm MLVSS

$$= \frac{\text{Uptake Rate}}{\text{MLVSS (g/l)}}$$

$$= \frac{28.8 \text{ mg } O_2\text{/l/hr}}{2.4 \text{ g/l}}$$

$$= 12 \text{ mg } O_2\text{/hr/gm MLVSS}$$

ORGANIC LOADING (BOD Volume Load)

Organic loading of a trickling filter refers to the daily pounds of BOD entering the trickling filter volume. This concept is expressed as

$$\text{Organic Loading} = \frac{\text{lbs BOD/day}}{\text{cu.ft.volume}}$$

EXAMPLE 1:

A standard rate trickling filter has a diameter of 108 feet and a media depth of 6 feet. The flow into the filter is 500 gallons per minute with a BOD concentration of 85 mg/l. What is the BOD loading per 1000 cu. ft.?

SOLUTION:

First we must determine the gallons per day flow

Pumping rate per minute = 500 gallons

$\therefore$ pumping rate per day = (500 gals/min)(1440 min/day)

= 720,000 gals/day

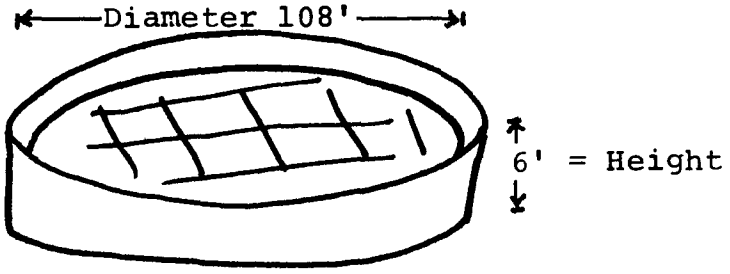
= .72 mgd

Next we calculate lbs BOD/day

$$85 \text{ mg/l} = \frac{85 \text{ lbs BOD}}{1 \text{ million lbs flow}} (.72 \text{ mgd})(10 \text{ lbs/gal})$$

= 612 lbs BOD/day

Because organic loading is a weight to volume relationship we must determine the volume of the trickling filter.



$$\text{Volume of a cylinder} = \frac{\pi D^2}{4} \times H$$

$$\text{Volume} = \frac{(3.14)(108)(108)}{4} \times 6' = 54937 \text{ ft}^3$$

Now we can utilize the relationship

$$\text{Organic Loading} = \frac{\text{lbs BOD/day}}{\text{cu. ft. volume}}$$

$$= \frac{612 \text{ lbs BOD/day}}{54{,}937 \text{ ft}^3}$$

$$= \frac{0.0111 \text{ lbs BOD/day}}{1 \text{ ft}^3}$$

However, we want our answer in terms of lbs BOD/1000 ft^3

$$\frac{0.0111 \text{ lbs BOD} \times 1000}{1 \text{ ft}^3 \quad \times 1000} = \frac{11.1 \text{ lbs BOD/day}}{1000 \text{ ft}^3}$$

ORGANIC LOADING

EXAMPLE 2:

An aeration tank has the following dimensions: 20' x 50' x 15'. The flow to the aeration tank is 1.3 MGD with a BOD concentration of 70 mg/l. Calculate the BOD loading per 1000 cu.ft.

SOLUTION:

Calculate lbs BOD/day

$$70 \text{ mg/l} = \frac{70 \text{ lbs BOD}}{1 \times 10^6 \text{ lbs flow}} \times 1.3 \times 10^6 \text{ gals} \times 10 \text{ lbs/gal}$$

$$= 910 \text{ lbs BOD/day}$$

Next, determine volume of aeration tank.

$$V = l \times w \times h$$
$$= 50' \times 20' \times 15'$$
$$= 15{,}000 \text{ cu.ft.}$$

Since Organic Loading $= \frac{\text{lbs BOD/day}}{\text{aeration tank volume(cu.ft.)}}$

$$\therefore \quad \frac{910 \text{ lbs BOD/day}}{15{,}000 \text{ cu.ft.}} = \frac{0.0607 \text{ lbs BOD/day}}{1 \text{ cu.ft.}}$$

Again, as in the previous example, the answer is to be in terms of lbs BOD/1000 cu.ft.

$$\therefore \quad \frac{0.0607 \text{ lbs BOD} \times 1000}{1 \text{ cu.ft.} \times 1000} = \frac{60.7 \text{ lbs. BOD}}{1000 \text{ cu.ft.}}$$

ACTIVATED SLUDGE PROBLEMS

(1) A 50 ml aliquot of mixed liquor is filtered for a suspended solids analysis. The tare weight of the paper is 0.174 gram. After filtering and drying, the paper weighed 0.324 gram. What is the MLSS concentration?

(2) Given a raw sewage flow of 1 MGD and a BOD in the raw sewage of 150 mg/l, calculate the lb. of BOD per day entering the activated sludge section assuming a 20% reduction in BOD across the primary clarifiers.

(3) Given that a plant has a daily flow of 1.0 MGD and an average primary effluent BOD of 150 mg/l, mixed liquor volatile suspended solids (MLVSS) of 1500 mg/l and an aeration tank volume of 200,000 gallons, calculate the F/M ratio.

(4) If the uptake rate is 20 mg O_2 /l/hr and the MLVSS is 4,000 mg/l, what is the specific uptake rate?

(5) A 100,000-gallon aeration tank contains 4,000 mg/l MLSS. The return sludge concentration is 12,000 mg/l. How many gallons of sludge should be wasted in order to reduce the MLSS to 3,000 mg/l?

(6) Calculate the MLSS and SVI using the following information:

(a) Weight of paper = 0.4004

(b) Weight of paper + solids = 0.5186

Sample volume = 50 mls

½ hour settleability test = 21%

(7) A 250-ml sample of final effluent is filtered for a suspended solids analysis. The tare weight of the paper is 0.1560 gram. After filtering and drying, the paper weight is 0.1572 gram. Express the suspended solids concentration in mg/l

(8) An aeration tank has a capacity of 500,000 gallons. If the MLSS is 3,000 mg/l, what is the weight of the solids expressed in lbs?

(9) The MLSS concentration in a 200,000-gallon aeration tank is 4,000 mg/l. This activated sludge contains 75% volatile suspended solids. Express the MLVSS in lbs.

(10) A flow of 1.7 mgd is entering a conventional activated sludge treatment plant. The BOD concentration in the raw sewage is 265 mg/l. If the primary treatment stage of the process removes 23% of the BOD and the F/M ratio in the aerator is 50 lbs BOD/100 lbs MLVSS, how many pounds MLVSS should be maintained in the aerator.

(11) The flow from the primary effluent to the aeration tank is 2.5 mgd with a suspended solids concentration of 87 mg/l. The mixed liquor suspended solids (MLSS) is 2075 mg/l in an aerator with the following dimensions of 90 feet long, 75 feet wide and with a water depth of 10 feet. Calculate the Sludge Age.

SECTION G

CHEMICAL FEEDING

Solution Preparation - Jar Tests

Jar tests are used to determine correct chemical dosages for such chemicals as alum, ferric chloride, activated silica. These are chemicals utilized in water treatment facilities for coagulation and flocculation of colloidal particles and are used in wastewater treatment facilities for chemical precipitation of phosphorous. The jar test simulates, on a small scale, the activities going on in various sections of the full scale treatment process. Varying amounts of the above mentioned chemicals are compared to see which chemical and dosage best accomplishes coagulation and flocculation in water treatment and the chemical precipitation of phosphorous in sewage treatment.

Stock solutions of coagulants, coagulant aids and other chemicals, should be prepared at concentrations such that quantities suitable for use in the jar tests can be measured accurately and conveniently. If one is dealing with dry chemicals the preparation of these stock solutions is quite straight forward. For example to prepare a 1% stock solution using dry chemicals 1 gram of the chemical is made up to 100 mls with water or 1 pound of chemical is mixed up to 100 pounds with water will give you the 1% solution. However, with concentrated liquid solutions a dilution step needs to be done. Any dilution step must take into account the specific gravity of the solution being diluted. For example, if one has a 48.5% alum solution with a specific gravity of 1.35 and wishes to make up a 1% stock solution the following procedure should be followed:

1 ml 48.5% liquid alum weighs 1.35 gm.

$$1 \text{ ml contains } 1.35 \times \frac{48.5}{100} = 0.65 \text{ gm alum}$$

$$\text{mls containing 1 gm Alum} = \frac{1}{.65} = 1.54 \text{ mls}$$

Therefore add 1.54 mls liquid alum to water and make up to 100 mls for a 1% solution.

CHEMICAL FEEDING

Water and Wastewater Operations

After jar tests have been carried out the type of chemical dosage and point of application best suited to the characteristics of the water or sewage to be treated should easily be established. The next step is to feed the chemical to be used at the dosage determined in the jar tests into the full scale treatment facility. The operator will be faced with using a dry chemical or a liquid chemical which will be fed into the process by means of a dry chemical feeder of a liquid chemical feeder. If feeding dry chemicals, the feeder will be calibrated most likely in grams per minute or if liquid chemicals are being utilized in millilitres per minute. Following is a detailed approach to establishing feed rates for chemicals.

Given a daily flow rate of 3.5 MGD and Fe^{+3} dosage of 13 mg/l, what is the ferric chloride ($FeCl_3$) flow rate in ml/min?

Ferric Chloride	13.9 lbs/gal
Fe^{+3}	13.7% by weight in the solution

Step 1. Determine lbs/day of Fe^{+3} required.

1. Fe^{+3} dosage of 13 mg/l = 13 ppm = $\frac{13 \text{ lbs.}}{1{,}000{,}000 \text{ lbs.}}$

2. Flow in lbs/day = Flow in gals/10 x $\frac{10 \text{ lbs}}{\text{gal}}$

3. Since flow is 3.5 MGD, dosage in lbs/day is

$$\frac{13 \text{ lbs.}}{1{,}000{,}000 \text{ lbs}} \times 3{,}500{,}000 \frac{\text{gals}}{\text{day}} \times 10 \frac{\text{lbs}}{\text{gal}}$$

$$= 455 \frac{\text{lbs}}{\text{day}} Fe^{+3}$$

Step 2. Determine lbs/day of solution.

Fe^{+3} is 13.7% by weight of solution.

∴ Amount of solution required is -

$$455 \times \frac{100}{13.7} = 3321.17 \frac{\text{lbs}}{\text{day}} \text{ of } FeCl_3 \text{ solution.}$$

Step 3. We are asked to give the flow rate in ml/min.

1. Convert lbs/day to gals/day

   Since 1 gal weighs 13.9 lbs

   3321.17 lbs represents $\frac{3321.17 \text{ lbs/day}}{13.9 \text{ lbs/gal}} = 238.9 \frac{\text{gal}}{\text{day}}$

2. Convert $\frac{\text{gals}}{\text{day}}$ to $\frac{\text{mls}}{\text{min}}$

   Since 1 gal is equivalent to 4546 mls

   $238.9 \frac{\text{gal}}{\text{day}} = 238.9 \times 4546 \frac{\text{mls}}{\text{day}}$

   Cpnverting mls/day to mls/minute

   $\frac{238.9 \times 4546}{1440} = 754.3$ ml/min.

EXAMPLE: Alum

In a water plant with an average daily outflow of .36 MGD 48% liquid alum is used at a dosage 55 mg/l. What alum feed rate measured in mls/min is needed?

Data: Alum is 13.4 lb/gal

48% wt/wt alum active ingredient as $Al_2(SO_4)_3 \cdot 14\ H_2O$

4.2% wt/wt Alum as Al^{+3}

$$55 \text{ mg/l Alum} = \frac{55}{1{,}000{,}000} \times 360{,}000 \text{ gal} \times 10 \text{ lb/gal}$$

$$= 198 \text{ lb/day}$$

lbs solution/day needed that contains = 198 lbs of alum

$$= \frac{198}{.485} = 408.25 \text{ lbs.}$$

$$\text{Hence volume needed} = 408.25 \text{ lbs/day} \times \frac{1 \text{ gal}}{13.4 \text{ lb}} = 30.47 \text{ gal/day}$$

$$\text{ml/min alum solution} = 30.47 \text{ gpd} \times \frac{1 \text{ day}}{24 \text{ hrs}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times 4546 \text{ mg/gal}$$

$$= 96.2 \text{ ml/min}$$

∴ For operations, the feed rate would be 96.2 ml/min.

CALCULATION OF FEED RATES USING A FORMULA

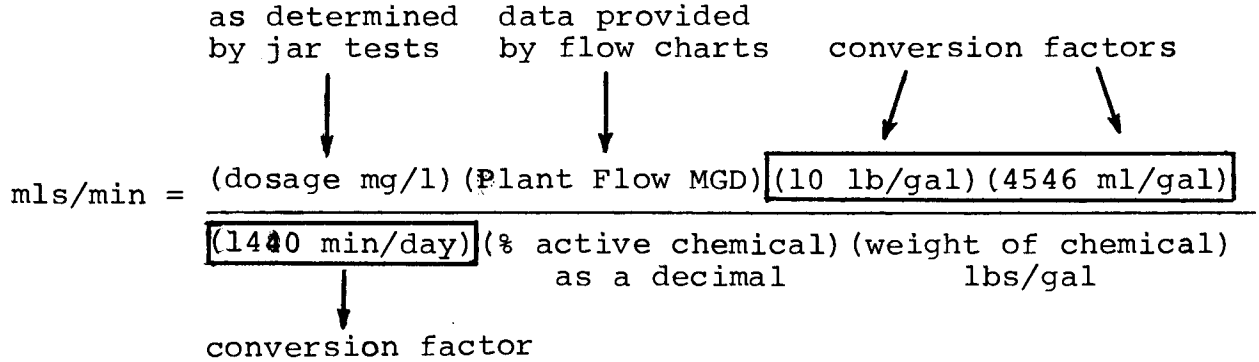
An alternate method of calculating feed rates in ml/min is through the use of a formula that takes into account all variables such as chemical concentrations, optimum dosages, plant flow, etc. Previously the long method was exemplified, however for practical applications the formula method is valid.

Figure I-1 below is a mathematical method for determining feed rates for chemical addition in millilitres per minute (ml/min), the normal units found on most liquid chemical feeders. These units of feed rate adopted from the metric system, soon to be introduced for all unit references, are utilized as they provide a convenient volume and time scale for calibration and accurate feeding of highly expensive and sometimes hazardous chemicals. Presently most treatment facilities record their flow rates in millions of gallons per day and order chemicals by the pound or gallon. These are Imperial system units.

Therefore it becomes necessary to relate plant data (Imperial Units) to chemical feeders (Metric Units). The formula takes these factors into account as well as variations in concentrations of chemicals and their specific gravity. Once proper dosage has been established through jar tests and daily flows from the flow chart and the variations in the chemicals' composition from the delivery tag this formula will provide the correct feed rate in millilitres per minute.

Figure I-1

FORMULA FOR FEED-RATE (mls/min)


as determined by jar tests
data provided by flow charts
conversion factors
mls/min =
(dosage mg/l)(Plant Flow MGD)(10 lb/gal)(4546 ml/gal)
(1440 min/day)(% active chemical as a decimal)(weight of chemical lbs/gal)
conversion factor

The formula contains conversion factors that are constants. These are indicated by the boxes in the formula.

If for ease of calculation we reduce these two conversion factors to one, the constant would be:

$$\frac{10 \text{ lbs/gal} \times 4546 \text{ ml/gal}}{1440 \text{ min/day}} \times 31.57$$

As a result, we can simplify the feed rate formula. Using the example, determination of alum feed rate (page 49) the calculation can be simplified thusly:

$$\text{ml/min} = \frac{(\text{dosage mg/l})\ (\text{Plant Flow MGD})}{(\%\text{ active chemical})\ (\text{weight of chemical})} = 31.57$$

(% active chemical) **a decimal fraction**; (weight of chemical) lb/gal

$$\text{ml/min} = \frac{(55 \text{ mg/l})\ (.36 \text{ MGD})}{(0.485)\ (13.4)} \times 31.57 = 96.2 \text{ ml/min}$$

or

96.2 ml/min

SECTION H

STOCK SOLUTIONS AND CHEMICAL FEED RATE PROBLEMS

1. How many mls of ferric chloride are needed to prepare 100 ml of a 1% solution of ferric chloride if the concentrated solution is 42.3% by weight and the specific gravity is 1.42?

2. How many mls of storage tank alum are required to make up 100 mls of a 1% solution for jar tests if the alum is 48% by weight (s.g. 1.34).

3. In a wastewater treatment plant with an average daily flow of 2.5 MGD, Alum is being used for phosphorous removal at a dosage of 450 mg/l. What alum flow rate, measured in mls/min is needed? (USE LONG METHOD FOR CALCULATION)

   DATA: Liquid alum weighs 13.5 lb/gal
   Liquid alum contains 48% wt/wt alum as $Al_2(SO_4)_3.14H_2O$
   Liquid alum contains 42% wt/wt Al^{+3}

4. In a water treatment plant both alum and activated silica are being used in the coagulation stage to help precipitate the colloidal suspensions. Jar tests indicated that 50 mg/l alum and 5.5 mg/l activated silica is the optimum dosage. Calculate, using the formula, the feed rate needed for each chemical in mls/min.

   DATA: Plant Flow 265 gallons per minute (gpm)
   Liquid Alum Weighs 13.5 lb/gal
   Liquid Alum contains 48.5% wt/wt alum as $Al_2(SO_4)_3.14H_2O$
   Activated Silica 1% wt/wt solution.

5. A plant has an average daily flow of 3.9 MGD and is dosing ferric chloride for phosphorus removal at 15 mg/l Fe^{+3}. What feed rate measured in mls/min is needed? Also how many gallons per day of ferric chloride is needed.

DATA: Liquid ferric chloride weighs 14.1
Ferric chloride contains 14.0% wt/wt Fe^{+3}
Ferric chloried contains 41.0% wt/wt $FeCl_3$

Milligrams Per Litre to Pounds Conversion

Milligrams per litre (mg/l) is a measurement used to express concentrations such as BOD, suspended solids, chemical dosages, etc. An additional method of reporting concentrations is in terms of parts per million (ppm) which is a weight to weight relationship whereas mg/l is a weight to volume relationship. These two terms mg/l and ppm are commonly used interchangeably because the specific gravity of water is 1. This signifies that 1 ml of water weighs 1 gram.

If, for example, a lab analysis reports a concentration of 1 mg/l, what does this mean?

Mathematically:

$$1 \text{ mg/l} = 1 \text{ ppm} = \frac{\text{one part}}{\text{1 million parts}}$$

Therefore if your consider 1000 ml of water (a litre) as weighing 1000 grams or 1,000,000 milligram (1 gm = 1000 mg) it becomes obvious that if you have a concentration of 1 mg/l this means you have 1 mg of solids for every 1 million mg of water.

$$1 \text{ mg/l} = \frac{1 \text{ mg} \times 1000}{1000 \text{ ml} \times 1000} = \frac{1000 \text{ mg}}{1{,}000{,}000 \text{ ml}} = \frac{\text{one part}}{1000{,}000 \text{ parts}}$$

The above is a simple mathematical proof to show that mg/l = ppm.

In a treatment facility it becomes necessary to sample various points in the process and the most practical method is to collect small but representative portions of the flow and report them in terms of mg/l. However, the results must be related to the fall scale facility and mg/l concentration must then be converted into pounds per day of BOD removal or pounds of sludge to be hauled away from the digestor or sedimentation tank.

When converting mg/l concentrations to pounds one must recall that mg/l is a weight to volume relationship and that the flow which contains the solids should be considered in terms of pounds and not gallons in relation to daily average flows.

EXAMPLE:

A wastewater treatment plant with an average daily flow of 2 MGD has a raw BOD of 250 mg/l and the effluent BOD is 15 mg/l. How many pounds of BOD are removed daily by this facility.

Solution:

incoming BOD	=	250 mg/l
effluent BOD	=	15 mg/l
BOD removed	=	235 mg/l

$\therefore$ lbs BOD/day removed =

$$\frac{235}{1{,}000{,}000} \text{ (concentration)} \times 2 \text{ MGD (flow)} \times 10 \text{ lbs/gal (conversion factor)} = 4700 \text{ lbs}$$

IMPERIAL/METRIC (SI) PARAMETERS AND CONVERSION FACTORS

This list should be used only as a guide, it being possible that experience may suggest the desirability of modifying some of the recommended units. Also consideration should be given to the numerical value when a unit is used in a particular context.

Parameter	Imperial unit	SI unit	Conversion factor
Rainfall	inches	mm	25·4
Sewer (diameter)	inches	mm	25·4
Sewage:			
Flow	gal/min	l/s	0·0758
	gal/d	m^3/d	0·004546
	mil gal/d	$10^3 m^3/d$	4·546
BOD per capita	lb BOD/hd d	kg BOD/hd d	0·4536
Pumping rate	gal/min	l/s	0·0758
Preliminary Treatment			
Screenings	ft^3/mil gal	$m^3/10^3 m^3$	0·00623
Grit removal:			
Velocity	ft/s	m/s	0·3048
Volume of grit	ft^3/mil gal	$m^3/10^3 m^3$	0·00623
Air	ft^3/min ft	m^3/min m	0·0929
Primary Treatment			
Capacity	gal/hd	l/hd	4·546
Surface loading	gal/ft^2 d	m^3/m^2 d	0·049
Upward-flow rate	ft/h	m/h	0·3048
Weir loading	gal/ft d	m^3/m d	0·0149
Scraper speed	ft/min	m/s	0·0051
Secondary Treatment			
Biological filters:			
Loading:			
Hydraulic	gal/yd^3 d	m^3/m^3 d	0·005946
Superficial	gal/yd^2 d	m^3/m^2 d	0·005437
BOD	lb BOD/yd^3 d	kg BOD/m^3 d	0·5932
Irrigation rate	gal/ft^2 h	m^3/m^2 h	0·049
Specific surface area	ft^2/ft^3	m^2/m^3	3·28
Activated-sludge plant:			
Loading	lb BOD/1000 ft^3 d	kg BOD/m^3 d	0·016
Sludge loading		g BOD/g activated sludge per day	
Sludge-volume index		ml/g	
Air	ft^3/gal	m^3/m^3	6·23
	ft^3/lb BOD removed	m^3/kg BOD removed	0·0624
	ft^3/min/ft^2 plan area	m^3/min/m^2 plan area	0·3048
Air pressure	lb/in^2	kN/m^2	6·895
Air compressor rating	ft^3/min	m^3/s	0·000472
Power	hp/mil gal d	W/m^3 d	0·164
Tertiary Treatment			
Sand filters:			
Loading	gal/ft^2 h	m^3/m^2 d	1·176
Backwashing rate	gal/ft^2 min	m^3/m^2 d	70·56
Grass plots	mil gal/acre d	m^3/m^2 d	1·123
Sludge Treatment			
Sludge:			
Volume	mil gal	m^3	4546
Production	gal/hd	m^3/hd	0·004546
	lb dry solids/hd d	kg dry solids/hd d	0·4536
	lb volatile matter/hd d	kg volatile matter/hd d	0·4536
Calorific value	Btu/lb	kJ/kg	2·326
Specific resistance	s^2/g at 500 g/cm^2	m/kg at 49 kN/m^2	$0·981 \times 10^4$
Sludge gas:			
Production	ft^3/lb volatile matter destroyed	m^3/kg volatile matter destroyed	0·0624
Calorific value	Btu/ft^3	kJ/m^3	37·26
Sludge dewatering:			
Yield	lb dry solids/ft^2 h	kg/m^2 h	4·881
Sludge digestion:			
Loading	lb volatile matter/ft^3 d	kg/m^3 d	16·03
Sludge heaters:			
Rating	10^6 Btu/h	GJ/h	1·055
Gas consumption	ft^3/h	m^3/h	0·02832
Fuel oil:			
Calorific value	Btu/gal	kJ/l	0·2321
	Btu/lb	kJ/kg	2·326

IMPERIAL/METRIC (SI) CONVERSION FACTORS

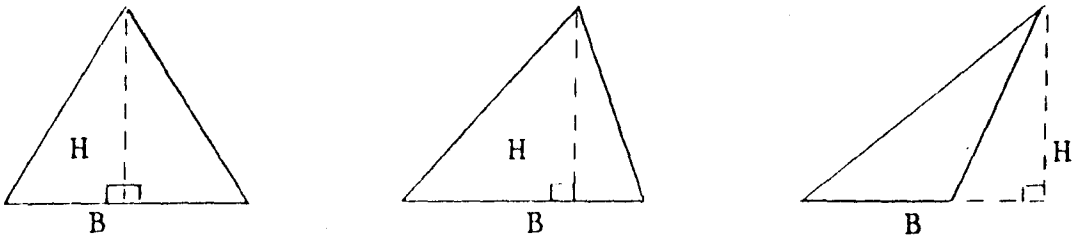
Multiply imperial unit by figure in multiplier column to obtain metric (SI) equivalent; multiply metric (SI) unit by reciprocal to obtain imperial equivalent.

Imperial Unit	Multiplier	Metric unit	Reciprocal
acre	0·4047	hectare	2·471
Btu	1·055	kJ	0·9478
Btu/ft² h	3·155	J/m² s	0·3170
Btu/ft³	37·26	kJ/m³	0·0268
Btu/gal	0·2321	kJ/l	4·31
Btu/lb	2·326	kJ/kg	0·43
°F	0·5555 (F − 32)	°C	(1·8 × °C) + 32
ft	0·3048	m	3·281
ft/min	0·0051	m/s	200
ft/s	0·3048	m/s	3·281
ft²	0·0929	m²	10·76
ft²/ft³	3·28	m²/m³	0·305
ft³	0·02832	m³	35·31
ft³/ft²	0·3048	m³/m²	3·281
ft³/gal	6·23	m³/m³	0·1605
ft³/lb	0·0624	m³/kg	16·1
ft³/mil gal	0·00623	m³/10³m³	160·51
ft³/min	0·000472	m³/s	2119
ft³/min ft	0·0929	m³/min m	10·764
ft³/min ft² plan area	0·3048	m³/min m² plan area	3·279
ft³/s (cusec)	0·02832	m³/s (cumec)	35·31
gal	4·546	litre	0·220
gal	0·004546	m³	220
gal/ft	0·0149	m³/m	67·114
gal/ft²	0·049	m³/m²	20·408
gal/ft² h	1·176	m³/m² d	0·850
gal/ft² min	70·56	m³/m² d	0·0142
gal/min	0·0758	l/s	13·192
gal/yd²	0·005437	m³/m²	183·9
gal/yd³	0·005946	m³/m³	168·2
hp	0·7457	kW	1·341
hp/mil gal	0·164	W/m³	6·098
in	25·40	mm	0·03937
in²	645·2	mm²	0·00155
in³	16·39 × 10³	mm³	0·061 × 10⁻³
lb	0·4536	kg	2·205
lb/ft²	4·881	kg/m²	0·2049
lb/ft³	16·03	kg/m³	0·06243
lb/10³ft³	0·016	kg/m³	62·5
lb/in²	6·895	kN/m²	0·1450
lb/yd³	0·5932	kg/m³	1·686
mil gal	4546	m³	0·220
mil gal/acre	1·123	m³/m²	0·890
mile	1·609	km	0·6214
ton	1·016	tonne	0·9842
yd	0·9144	m	1·094
yd²	0·8361	m²	1·196
yd³	0·7646	m³	1·308

A water works operator is often called upon to figure out areas and volumes. The types of figures which he is most likely to encounter are shown below:

Areas

(1) Triangle

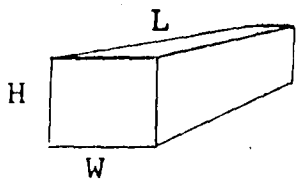


The area of a triangle:

$$A = \frac{1}{2} \text{ base x height}$$

$$= \frac{1}{2} B \times H$$

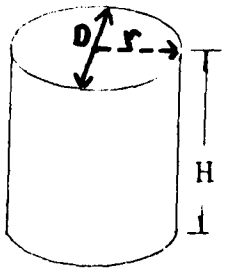
(2) Rectangular Solid



The volume of a rectangular solid:

$$V = L \times W \times H$$

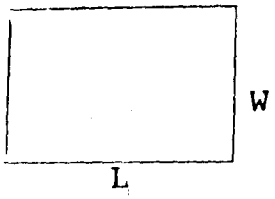
(3) Cylinder



The volume of a cylinder:

$$V = \frac{\pi D^2}{4} \times H$$

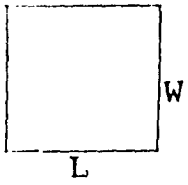
(2) Rectangle



The area of a rectangle:

$$A = L \times W$$

(3) Square



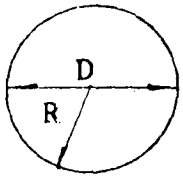
The area of a square:

$$A = L \times W$$

but $L = W$

Therefore $A = L^2$

(4) Circle



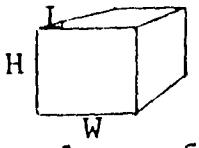
D = diameter
R = radius = 1/2D
C = circumference
π = 3.14

The area of a circle:

$$A = \pi R^2 \quad \text{or} \quad \frac{\pi D^2}{4}$$

Volumes

(1) Cube



all three sides equal
L = W = H

The volume of a cube:

$$V = L \times W \times H = L^3$$

HANDY CONVERSION TABLE

LINEAR

1 inch (in)	=	2.540 centimetres (cm)
1 foot (ft)	=	12 inches (in)
1 yard (yd)	=	3 feet (ft)
1 mile (mi)	=	5,280 feet
1 meter (m)	=	39.37 in. = 3.281 ft= 1.094 yd.
1 meter	=	100 centimetres

AREA

1 square foot (ft^2)	=	144 square inches (in^2)
1 square yard (yd^2)	=	9 square feet
1 acre	=	43,560 square feet
1 square mile	=	640 acres

VOLUME

1 cubic foot (ft^3)	=	1728 cubic inches (in^3)
1 cubic yard (yd^3)	=	27 cubic feet (ft^3)
1 cubic foot	=	6.24 gallons (Imp.gals)
1 gallon	=	4 quarts (qts.)
1 litre	=	1000 millilitres (ml)

WEIGHT

1 pound (lb)	=	16 ounces = 7000 grains= 453.6 grams
1 ounce (oz.)	=	28.35 grams (gms.)
1 kilogram (kg)	=	1000 grams
1 gram	=	1000 milligrams (mg)
1 cu.ft. water	=	62.4 pounds (lbs.)
1 gallon water	=	10 pounds water
1 litre water	=	1 kilogram water
1 millilitre water	=	1 gram water

SUMMARY OF WATER AND WASTEWATER FORMULAE

HANDY FORMULAE CHART

$$\text{Average Daily Flow} = \frac{\text{total sum of all daily flows}}{\text{number of days}}$$

Flow in rectangular channel in Cubic Feet/sec (ft^3/sec)

= (width ft)(depth ft)(velocity ft/sec)

Flow in a circular channel (or pipe) in Cubic Feet/sec (ft^3/sec)

= (cross sectional wetted area of circle)(velocity ft^3/sec)

$$\text{Weir Overflow Rate (gpm/linear ft)} = \frac{\text{gpm flow}}{\text{total feet of weir}}$$

Pumping Rate (gpm) = Influent Rate (gpm) - gpm due to level change after pump is started

$$\text{Hydraulic Loading (gals/sq ft/day)} = \frac{\text{gpd flow}}{\text{sq.ft.surface area}}$$

$$\text{F/M Ratio} = \frac{\text{lbs BOD/day to aeration tanks}}{\text{lbs MLVSS in aeration tanks}}$$

$$\text{MLSS} = \frac{(B - A) \times 1000 \times 1000}{V}$$

B= dried weight of disc + solids (gm)

A= dried disc weight (gm)

V= volume of sample (ml)

$$\text{Organic Loading} = \frac{\text{lbs BOD/day}}{\text{cu.ft. volume}}$$

Sludge Volume Index (SVI)

$$= \frac{\text{30 minute settling test result (ml) in 1000 ml cylinder}}{\text{MLSS (mg/l)}} \times 100$$

$$\text{\% Suspended Solids removed} = \frac{\text{mg/l suspended solids removed} \times 100}{\text{total mg/l suspended solids}}$$

$$\text{\% Settled Sludge} = \frac{\text{ml settled sludge} \times 100}{\text{ml total sample}}$$

$$\text{Chlorine Dosage} = \text{Chlorine Demand} + \text{Chlorine Residual}$$

Fahrenheit Degrees to Celsius Degrees:

$$C^{o} = \frac{5}{9} (F^{o} - 32^{o})$$

Celsius Degrees to Fahrenheit Degrees:

$$F^{o} = \frac{9}{5} (C^{o}) + 32^{o}$$